A Biomechanic Study of the Surgical Repair Technique of Pars Defect in Spondylolysis

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Abstract

To find out which wiring technique of direct repair of the pars defect is the strongest in resisting anteroposterior translation displacement, fifteen fresh human cadaveric L_4-L_5 spines were biomechanically tested by a universal testing machine. Two millimeters wide pars defect was created on both sides of L_4 vertebrae. Each of the five specimens was wired using Nicol's technique (A), modified Nicol's technique (B) and modified pedicular screw technique respectively (C). At each test, motion was observed to occur initially at the pars defect. The mean minimum tensile strength (increment of the pars defect) for technique A, B and C was 87.64, 82.04 and 110.08 Kg Force respectively. By statistical analysis, technique C was the strongest in resisting anteroposterior displacement of the spinal column. There was no statistically significant difference between technique A and B.

The following statement, "the arch of the fifth lumbar vertebra is separated from the articulating process" represents the first description of spondylolysis in English(1). Neugebauer was the first author to use the word spondylolysis in his report(2). The significance of structural integrity of the lamina for lumbosacral stability was first recognized by Robert zu Coblenz(2). Pars defect has been shown to relate with the instability which may initiate early degradation of the intervertebral disc of the involved segement(3,4). Motion that occurs in the pars defect can lead to irritation of its own nerve roots that are located adjacent to the pars interarticularis in the superior portion of the foramen. The interposed tissue within the pars defect has been implicated as one possible source of pain in some patients(5). The concept of retaining the anatomy for the lytic defect of lumbar spondylolysis is not new. Direct repair of the pars defect with bone graft using several fixations has been reported in the literature. The advantages of intrasegmental repair are a high rate of defect healing

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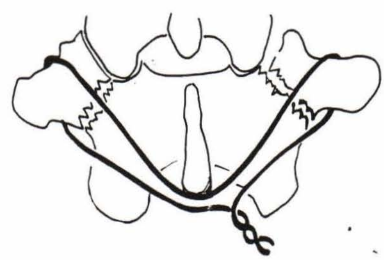
and preservation of lumbar motion without jeopardising the functional anatomy of the spine. Nicol's technique of repair involved placing 20-gauge stainless steel around the transverse process. The wire ends were passed caudal to the spinous process. Modification of this technique by pedicular screw can reduce the complication while passing a wire around the transverse process and can allow a more compression across the pars defect. Clinically, we modified the Nicol's technique by using figure of 8 wiring (18 gaurge stainless steel) since 1991 and in 1993 we used a pedicular screw instead of placing a wire around the transverse process. The purpose of this report was to compare the stiffness of the three wiring techniques: A, the Nicol's technique B, modified Nicol's technique (figure of 8 wiring) and C, pedicular screw technique

MATERIAL AND METHOD

Fifteen fresh human cadaveric specimens (age range 20-40 years) including L4-L5 were dissected free of all muscles. The intervertebral ligaments, discs and facet joints were all preserved. Two millimeters wide pars defects were created using a high speed saw at L_4 vertebrae respectively (Fig. 1). Each of the five specimens was wired using Nicol's technique (A) (Fig. 2A), modified Nicol's technique (B) (Fig. 2B) and modified pedicular screws technique (C) (Fig. 2C) respectively. A universal testing machine (Chimadzu AG 2000, Japan) with two mechanical grips was used to test the anteroposterior translation of the spine columns. The tensile load was set to 2 mm per minute. One special grip held the neural arch, another grip was connected to the Kirschner wires that passed mediolaterally through the vertebral body (Fig. 3). The force that subjected the motion to occur at the pars defect was defined as the minimum tensile strength which was recorded in each test as Kg Force. This increment of the pars defect more than 2 mm was demonstrated by the Vernier caliper.

RESULTS

When the spine column was tested, the motion was observed to occur initially at the pars defect. The mean minimum tensile strength for wiring technique A, B and C was 87.64 Kg Force, 82.04 Kg Force and 110.08 Kg Force respectively Completely randomized design was used for statistical analysis as each test was independent of one another (Table 1). With ANOVA table and least



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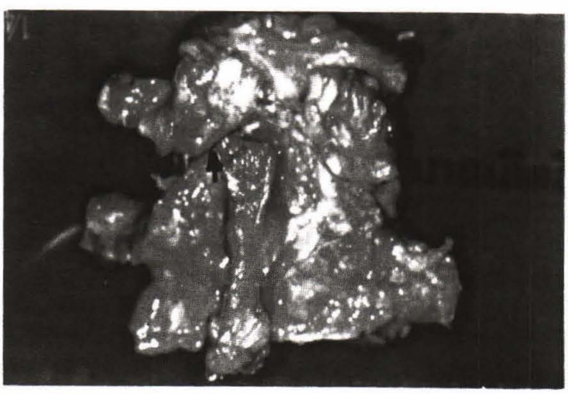


Fig. 1. Pars defect (arrow) is shown at L_4 vertebra in one fresh specimen.

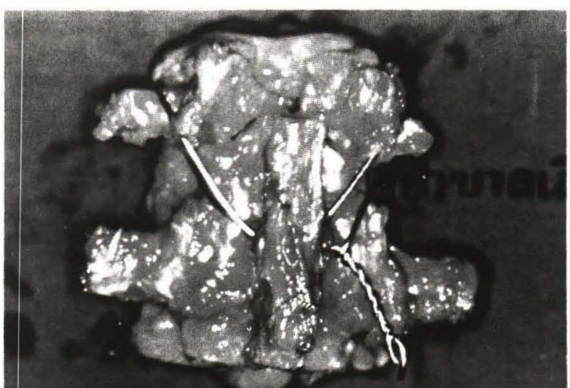
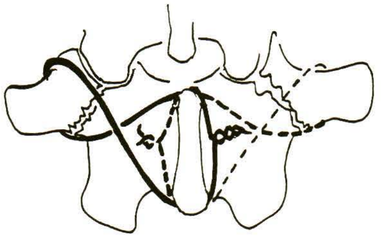
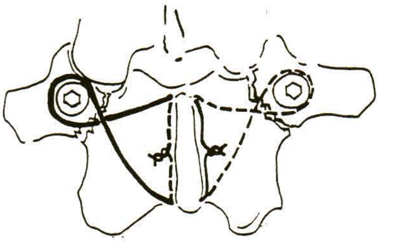


Fig. 2A. Nicol's wiring technique, the wire is passed around both transverse process. The wires are tightening to each other under the spinous process.





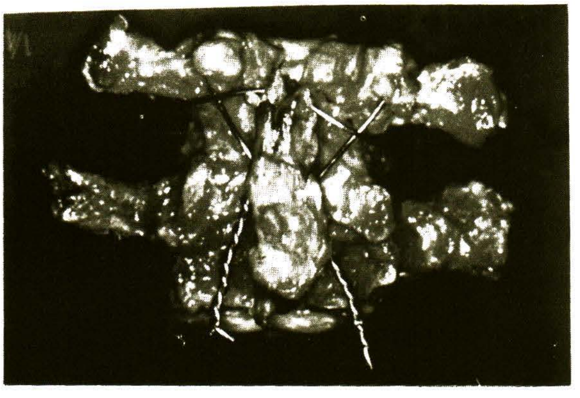


Fig. 2B. **Modified Nicol's technique, the wire is passed around the transverse process and spinous process by figure of 8 pattern.**

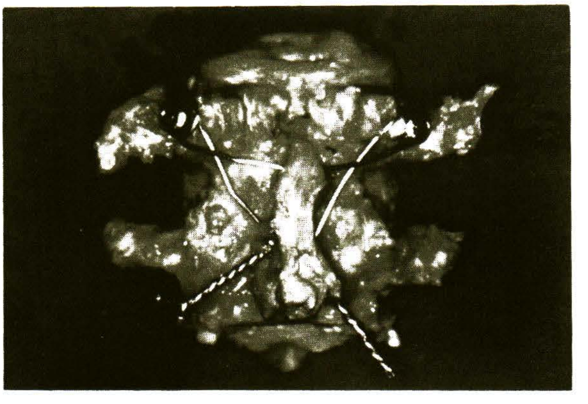


Fig. 2C. **Pedicular screw technique, the wire is passed around head of the screw and spinous process.**

Table 1. **Shows the mean, SD and 95% confidence interval for each technique.**

	Analysis of variance				
Source	D.F.	Sum of squares	Mean squares	F ratio	F Prob.
Between group	2	2201.9253	1100.9627	7.4864	0.0078
Within groups	12	1764.7520	147.0627		
Total	14	3966.6773			

Group	Count	Mean	Standard deviation	Standard error	95% confidence interval for each technique		
tech A	5	87.6400	11.9310	5.3357	72.8260	To	102.4540
tech B	5	82.0400	11.5891	5.1828	67.6504	To	96.4296
tech C	5	110.0800	12.8270	5.7364	94.1534	To	126.0066
Total	15	93.2533	16.8325	4.3464	83.9318	To	102.5749

Group	Miminum	Maximun
tech A	78.6000	108.2000
tech B	66.4000	98.6000
tech C	92.2000	126.8000

Table 2. Shows the LSD procedure, technique C is the strongest.

Homogeneous subsets (Subsets of groups, whose highest and lowest means do not differ by more than the shortest significant range for a subset of that size)

Subset 1		
Group	tech B	tech A
Mean	82.0400	87.6400
Subset 2		
Group	tech C	
Mean	110.0800	

significant difference (LSD) procedure, we found technique C had a statistically signficant increase in translation stiffness (Table 2). This means that technique C was the strongest to resist anterior posterior translation. There was no statistically significant difference between technique A and technique B.

DISCUSSION

Instability of the intact vertebrae can occur due to degenerative changes of the discs and facet

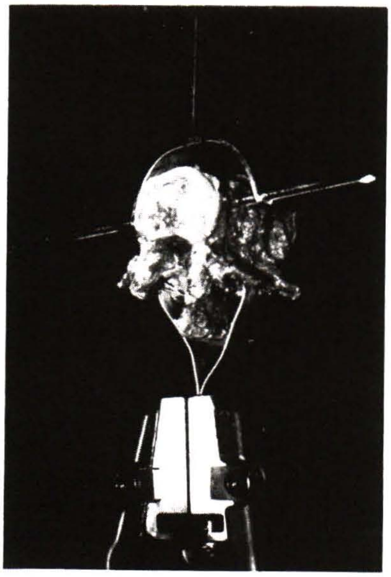


Fig. 3. The L_4-L_5 specimen is seen held by the special grip of the testing machine ready for the AP translating test.

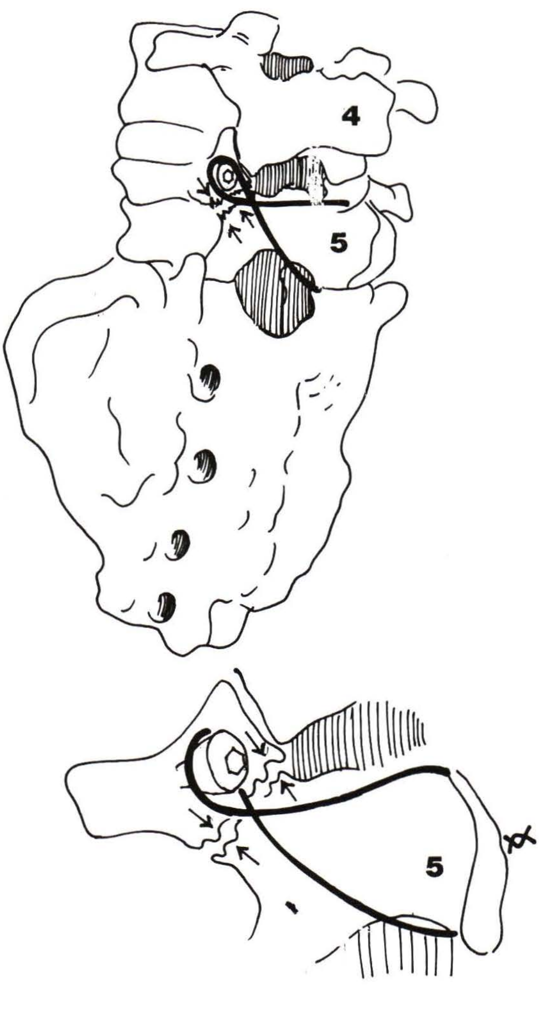


Fig. 4. The figure of 8 wire loop (tension band technique) can provide compression force across the pars defect by tightening the wires around the spinous process and head of the pedicular screw.

joints. If there is a defect in the pars, then only the disc can provide stability for the spine. Instability of the spine with a lytic defect has been demonstrated by biomechanical study(6). The instability of the loose fragment can cause root pain and subject the spine for further slip and later development of degenerative process(3,4,7). Direct repair of the pars defect can restore the anatomy and preserve the functional capacity of the normal spine. High rate of success has been reported by several fixation techniques and autogenous graft(5-8). Nicol proposed the use of stainless steel wire around the transverse process bilaterally, the wires were tightened to each other under the spinous process(8). From biomechanical study the wiring technique can produce a significant increase in bending stiffness of spondylolytic lumbar segment(6) but passing a wire loop around the transverse process is difficult and has variable seating. The inter and intrasegmental wiring have been claimed as a tension band wiring technique(6). The principle of the tension band wiring can provide dynamic compression and can absorb the tensile forces acting on the fracture site. Normally for tension band wiring, one end of the wire loop should pass through bone or through tendinous structure close to the bone, the other loop is usually passed around the projecting ends of the Kirschner wires. With the current technique, one wire loop is placed around the screw head which can result in a more uniform force, while another loop is placed around the spinous process in which the posterior ligament complex of the spine can act similarly to the muscle tendon of the long bone (Fig. 4). This modification by crossing the figure of 8 wire loop over the fracture line can provide more compression force on the pars defect. Our biomechanical test indicated that the modified pedicular screws technique (technique C) was the strongest fixation. Clinically, we have used this technique to repair the pars defect with great success. Patients can have early ambulation without external support. Immediate stabilization of the pars defect can be demonstrated intraoperatively following the wire tightening.

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การศึกษาเชิงเครื่องกล วิธีการผ่าตัดเพื่อซ่อมรอยกระดูกหักของ pars ใน spondylolysis

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คณะผู้รายงานได้ทำการเปรียบเทียบความแข็งแรงของวิธีการมัดลวด 3 แบบ เพื่อซ่อมแซมรอยหักตรง pars interarticularis โดยทดลองเชิงเครื่องกลในกระดูกหลังของศพจำนวน 15 ชิ้น

- วิธีการมัดลวดแบบ A เป็นวิธีการมัดลวดตามเทคนิคของ Nicol
- วิธีการมัดลวดแบบ B เป็นวิธีการดัดแปลงโดยคล้องลวดเป็นรูปเลข 8
- วิธีการแบบ C เป็นวิธีการมัดลวดโดยคล้องผ่านสกรูที่ยึดผ่านกระดูก pedicle

แต่ละวิธีใช้กระดูกหลัง 5 ชิ้น ตัดกระดูกตรง pars interarticularis ให้ขาดจากกัน มัดลวดแต่ละวิธีและวัดความแข็งแรงโดยใช้เครื่องตรวจมาตรฐาน พบว่าแรงที่ใช้เพื่อให้เกิดการเคลื่อนที่ของรอยหักของ pars ตามเทคนิค A, B และ C คือ 87.64, 82.04 และ 110.08 กิโลกรัม/แรง หมายความว่าเทคนิค C ที่คล้องลวดผ่านสกรูมีความแข็งแรงที่สุด เทคนิค A และ B แข็งแรงเท่ากัน

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